"Flow in pipelines"

1) Crude oil at 20 °c flows in riveted steel pipe 1.00 m in diameter at a mean velocity of 2.0 m/s. What range of head loss is to be expected in 1 km of pipelines? For Crude oil at 20°c: v=8.391 $*10^{-6}$ m^2/s

Data:

$d = 1m$

$V = 2 m/s$ $\nu = 8.391 * 10^{-6} m^2/s.$

What: rang of head Loss is to be expected in 1 km of Pipe line?

Solution

$$Re = \frac{Vd}{\nu} = \frac{2 * 1}{8.391 * 10^{-6}} = 2.4 * 10^{5}$$

From relative roughness chart at riveted steal Pipe 1m diameter

$$\frac{e}{d} = 0.0009 \text{ to } 0.009$$

From Moody chart at $Re = 2.4 * 10^{5}$ and

$$\frac{e}{d} = 0.0009 \longrightarrow f = 0.0205$$

$$\frac{e}{d} = 0.009 \longrightarrow f = 0.0365$$

$$h_L = f \frac{L}{d} \frac{V^2}{2g} = 0.0205 * \frac{1000}{1} * \frac{(2)^2}{2 * 9.8} = 4.2\ m$$

$$h_L = f \frac{L}{d} \frac{V^2}{2g} = 0.0365 * \frac{1000}{1} * \frac{(2)^2}{2 * 9.8} = 7.4\ m$$

The range of head Loss is 4.2m to 7.4m Per 1 Km.

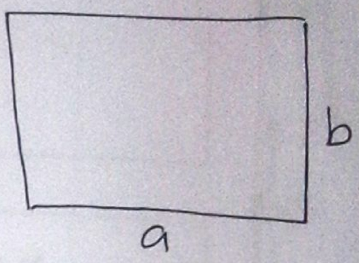
2) Calculate the loss of head and the pressure drop when air at an absolute pressure of 101.3 kPa and 15 °c (ρ=1.225 kg/m³) flows through 600 m of 450 mm by 300 mm smooth rectangular duct with a mean velocity of 3 m/s.

For air at 15°c: $v=1.46 * 10^{-5}$ m²/s

Data: $P = 101.3$ KPa , $T = 15$ c° ($\rho_a = 1.225$ Kg/m³)

$L = 600$ m , $a = 450$ MM , $b = 300$ MM

$V = 3$ m/s. $\nu_a = 1.46 * 10^{-5}$ m²/s



Calculate: h_L and ΔP

Solution

$$d_h = \frac{4 * \text{Area}}{\text{wetted Perimeter}} = \frac{4(0.45 * 0.30)}{2(0.45 + 0.30)} = 0.36 \text{ m}$$

$$Re = \frac{V d_h}{\nu} = \frac{3 * 0.36}{1.46 * 10^{-5}} = 73\,950$$

From Moody diagram at Re = 73950 and smooth Pipe line.

$$f = 0.019$$

$$h_L = f \frac{L}{d_h} \frac{V^2}{2g} = 0.019 * \frac{600}{0.36} * \frac{(3)^2}{2 * 9.8} = 14.5 \text{ m of air}$$

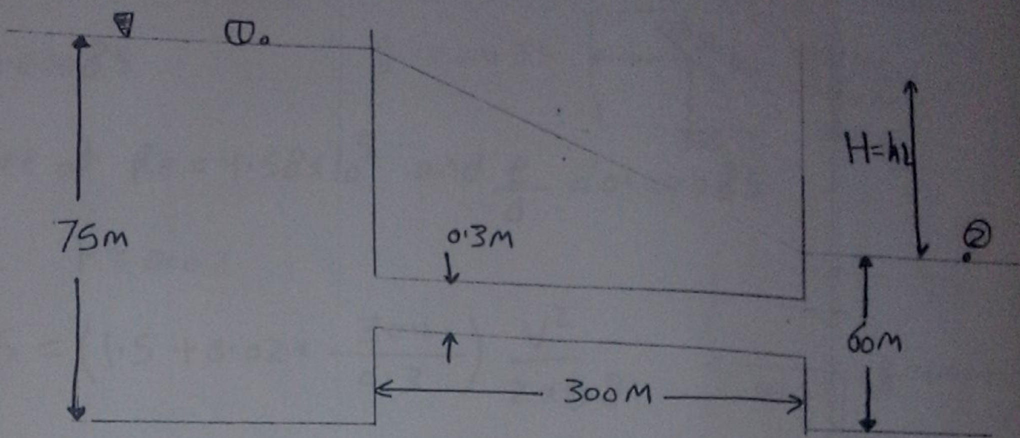
$$\boxed{h_L = 14.5 \text{ m of air}}$$ #

$$\Delta P = \rho g h_L = 1.225 * 9.8 * 14.5$$

$$\boxed{\Delta P = 174 \text{ Pa.}}$$ #

3) A clean cast iron pipeline 0.30 m in diameter and 300 m long connects two reservoirs having surface elevation 60 m and 75 m. calculate the flow rate through this line, assuming water at 10 °c and a square – edged entrance.

For water at 10°c: $v=1.306 * 10^{-6} m^2/s$



Data: Pipe: clean cast iron $d=0.30\,m$, $L=300\,m$.

Fluid: water at 10c° $\nu=1.306 \times 10^{-6}\,m^2/s$.

$Z_1=75\,m$, $Z_2=60\,m$, a square - edged entrance.

Calculate: Q (flow rate)

Solution

Apply Bernoulli equation between ① and ②

$$\cancel{\frac{P_1}{\gamma}} + \cancel{\frac{V_1^2}{2g}} + Z_1 = \cancel{\frac{P_2}{\gamma}} + \cancel{\frac{V_2^2}{2g}} + Z_2 + h_{L_{1-2}}$$

$$Z_1 - Z_2 = H = h_{L_{1-2}} = h_{L_e} + h_f + h_{Lx}$$

From tables

$K_e = 0.5$

$K_x = 1$

$$15 = \left(0.5 + \frac{fL}{d} + 1\right)\frac{V^2}{2g}$$

$$\boxed{15 = \left(1.5 + f * \frac{300}{0.3}\right)\frac{V^2}{2*9.8}}$$

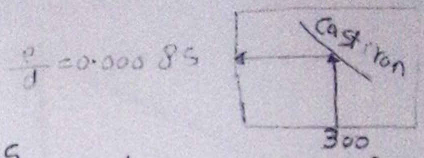
5)

assume V=2 m/s (2-4 m/s) velocity range.

$$Re = \frac{Vd}{\nu} = \frac{2 * 0.3}{1.306 * 10^{-6}} = 458000$$

From relative roughness chart at d=300 mm and Cast iron pipe

$$\frac{e}{d} = 0.00085$$



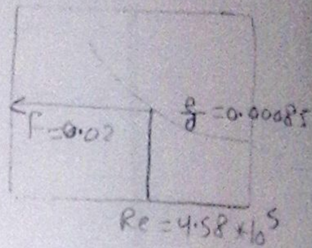
relative roughness chart

from moody chart at $Re = 4.58*10^5$ and $\frac{e}{d} = 0.00085$

$$f = 0.02$$

$$15 = \left(1.5 + 0.02 * \frac{300}{0.3}\right)\frac{V^2}{2*9.8}$$

$$V = 3.7 \text{ m/s}.$$



Moody chart

assume V = 3.7 m/s

$$Re = \frac{Vd}{\nu} = \frac{3.7 * 0.3}{1.306 * 10^{-6}} = 847250$$

from moody chart at $Re = 8.47 * 10^5$ and $\frac{e}{d} = 0.00085$

$$f = 0.0193$$

$$15 = \left(1.5 + 0.0193 * \frac{300}{0.3}\right)\frac{V^2}{2*9.8}$$

$$\boxed{V = 3.67 \text{ m/s.}}$$ accepted,

$$Q = A \cdot V = \frac{\pi}{4}(0.3)^2 * 3.67$$

$$\boxed{Q = 0.266 \text{ m}^3/\text{s}}$$ #

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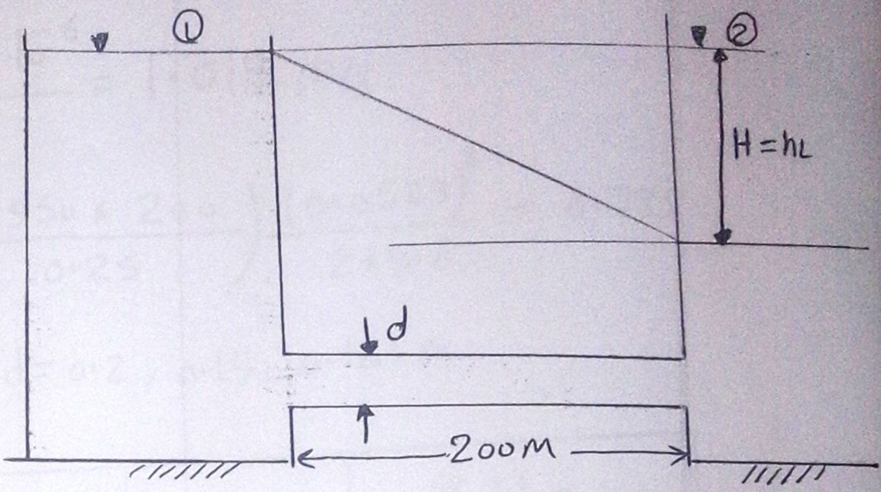
4) A smooth PVC pipeline 200 m long is to carry a flow rate 0.05 m^3/s between two tanks whose difference in surface elevation is 8 m. If a square-edged entrance and water at 10 °c are assumed, what diameter of pipe is required? For water at 10 °c : $v=1.306 * 10^{-6}\ m^2/s$



Data:

A smooth PVC Pipeline

$L = 200\ m$

$Q = 0.05\ m^3/s$

$H = 8\ m$

$\nu = 1.306 * 10^{-6}\ m^2/s$

Determine: Pipe diameter (d)

Solution

Apply Bernoulli eqn between ① and ②

From tables

$k_e = 0.5$

$k_x = 1$

$$H = \left(0.5 + \frac{fL}{d} + 1\right)\frac{V^2}{2g}$$

$$\boxed{8 = \left(1.5 + \frac{f * 200}{d}\right)\frac{V^2}{2 * 9.8}}$$

$$Re = \frac{Vd}{\nu} = \left(\frac{Q}{A}\right)\frac{d}{\nu} = \frac{Qd}{\frac{\pi}{4}d^2 \cdot \nu} = \frac{4Q}{\pi d \nu} = \frac{4 * 0.05}{\pi * d * 1.306 * 10^{-6}}$$

$$Re = \frac{48745.8}{d}$$

$$Re = \frac{Vd}{\nu} \rightarrow V = \frac{Re \cdot \nu}{d} = \frac{48745.8 * 1.306 * 10^{-6}}{d^2}$$

assume $d = 0.25\,m$

$$\therefore Re = \frac{48745.8}{0.25} = 194983.2$$

From Moody chart at $Re = 194983.2$ and smooth pipe.

$$f = 0.01550$$

$$V = \frac{48745.8 * 1.306 * 10^{-6}}{(0.25)^2} = 1.019\ m/s$$

$$R.H.S = \left(1.5 + \frac{0.01550 * 200}{0.25}\right)\frac{(0.0529)^2}{2 * 9.8} = 0.735$$

Repeat the problem at $d = 0.2,\ 0.15,\ 0.151\,m$

Assume d	Re	f	V	R.H.S
0.25	194983.2	0.01550	1.019	0.735
0.2	243729	0.01480	1.592	2.106
0.15	324972	0.01400	2.829	8.227
0.151	322819.9	0.01408	2.792	8.005

$\therefore d = 0.151\,m$

$\therefore$ $\boxed{\text{Pipe diameter } (d) = 151\ mm}$ #

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From Moody chart at Re = 194983.2 and smooth pipe.

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5) A clean cast iron pipeline 0.26 m in diameter and 200 m long connects two reservoirs having surface elevation 60 m and 160 m. if given: e/d=0.001, $v_w=1.3*10^{-6}$ m^2/s, $Re>2*10^6$, moody diagram, $K_L=0.5$ for a square edge entrance, $K_L=1$ for exit into reservoir ,

- Calculate the flow rate through this pipeline.
- Check the flow type in the above pipeline.

Data:

clean Cast iron.

$d=0.26\,m$

$L=200\,m$

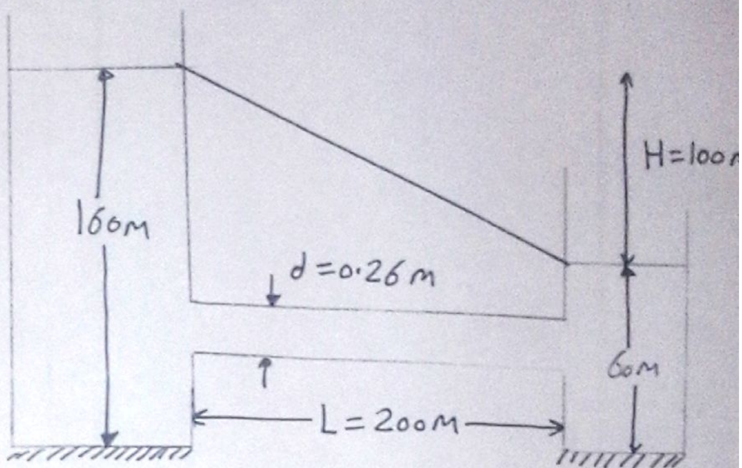
$Z_1=160\,m$, $Z_2=60\,m$

$\frac{e}{d}=0.001$

$\nu_w=1.3*10^{-6}\,m^2/s$

$Re>2*10^6$, $K_{Le}=0.5$, $K_{Lx}=1$

Calculate: Q check: the flow type



Solution

from Moody chart at $\frac{e}{d}=0.001$ and $Re>2*10^6$

$f=0.0196=\text{Const}.$

$$H=h_{Le}+h_{Lf}+h_{Lx}$$

$$100=\left(0.5+0.0196*\frac{200}{0.26}+1\right)\frac{V^2}{2*9.81}$$

$V=10.879\,m/s.$

$$Q=V\cdot A=10.879*\frac{\pi}{4}(0.26)^2=0.5776\,m^3/s$$

$\boxed{Q=0.5776\,m^3/s}$ #

$$Re=\frac{Vd}{\nu}=\frac{10.879*0.26}{1.3*10^{-6}}=2175800$$

$Re>2*10^6$ → $\boxed{\text{the flow is rough.}}$ #